ART. I.—*On the Evidences of a Glacial Epoch in Victoria During Post-Miocene Times.*

BY G. S. GRIFFITHS.

[Read 13th March, 1884.]

HAVING had occasion to pay frequent visits to our goldfields, the boulder washes which accompany many of our alluviums, especially the richer ones, have always excited my wonder and curiosity. The heavy boulders of which they are composed are embedded in a matrix of silicious cement, or of hard clay, and the formation is found in strips and sheets, flooring our leads and valleys, capping our hills, and terracing our mountains; and they sometimes stream across country, traversing the gullies and ranges, regardless of the levels or of the drainage lines.

These conglomerates are generally believed to be the remnants of ancient and deserted river beds. We are told that the streams which deposited them have since shrunk into trickling rivulets, and that, meanwhile, their courses have shifted from time to time, until, at last, they for ever left their old beds, although we now know, on the best authority, that the river system of a country is even more ancient, more permanent, more indelible, than its mountain system ("Rivers and River Gorges," A. Geikie, in *Eng. Ill. Mag.*, Jan., 1884). That as they shifted about they left behind them, as well as above, these ancient, stone-paved beds, winding about aimlessly and crossing older tracks, until the geological map which records them is covered with a network of lines. We are told, also, that the denudation which this country has undergone is very great in amount, and that it has entirely changed the aspect of hill and vale, so much so that we find, here and there, old river beds running along the backs of spurs, as is the case at Cobungra.

This explanation, although it contains many truths, does not seem, to me, to be entirely satisfactory; and the more carefully I examine the boulder washes the less do I feel disposed to acquiesce in it.

The facts which are not explained by the fluvial theory may be briefly stated.

In the first place, the observer is struck by the frequency with which washes containing huge boulders occur close to the sources of small rivulets. These insignificant gutters of intermittent flow are quite inadequate in power to carve out this drift. A stream of water with some volume is required for the purpose. To get a stream a watershed is necessary, but the gathering ground of some of the gullies which contain these boulders in abundance is insignificant. Thus, the water-power required is not only wanting, but, to all appearance, always has been. This is not merely my own individual opinion, but it is one which has been expressed strongly by many geologists.

On a col. between Mounts Lookout and Taylor, in Gippsland, Mr. A. W. Howitt reports a wash of boulders and rolled gravel (Smyth's *Goldfields*, p. 123). On this saddle there is no stream, and no watershed to feed one; even the surface runnels cannot unite until they reach the lower ground, where the hill flanks gather themselves up into folds and troughs. Nor can it be shown that where the saddle now stands a watershed ever has served it, and has since been removed by erosion. The only effect of erosion is that the saddle has been lowered. In what manner, then, has flowing water cut out and laid down this boulder bed ?

We find similar deposits placed high up the flanks of the Warrenheip Range, 1750 feet above the sea level. The boulders are of immense size, and the wash has been traced along the valley for miles. It once filled up the whole depression, but now only remnants fringe the sides (Murray's *Rep. Ballarat Geo. Survey, Vict.*, p. 66).

At Creswick, on two hills, there is a deposit which varies in thickness between 4 and 60 feet. It occurs at an elevation of 1400 feet, and consists of brown clay, quartz, gravel, pebbles, and boulders. Some of the latter are as much as four feet in diameter, and weigh over a ton. The age of this deposit is lower pliocene (Lock's *Gold*, p. 931).

Krausé describes a drift near Ararat, at 1100 feet above the sea level, which is a mixture of clay, gravel, and angular boulders, and which is occasionally 100 feet thick. In his report he points out that these large boulders are found at the very sources of the leads, where little or no fluvial action can have taken place (*Gold*, p. 650).

Without multiplying such instances any further, I will quote to you an opinion expressed many years ago by Selwyn, who wrote as follows :—" The wide spread of the formation over hill, plain, and valley, its uniform character, and the peculiar rounded and water-worn nature of much of the material composing it, are features that appear to require for their production some cause having a much more extended, uniform, and powerful action than can well be ascribed to river floods" (Selwyn's *Notes on Vict.*, p. 25). Similar opinions have been expressed by Murray (*Geo. Sur. Rep.*, p. 68), Krausé (*Gold*, p. 650), Brough Smyth (*Goldfields*, p. 154), Howitt, and others.

When we reflect upon the transport power of running water, as it is exemplified around us, we must feel still more dubious of the fluvial origin of these drifts. If we turn to the well-observed rivers of Great Britain, we find that three miles an hour is the maximum speed of the Thames, the Clyde, and the Tay, and that one and a half miles per hour is a moderately swift current (*Stevenson on Reclamation*, p. 18). Further, we see that a velocity of one and a third miles per hour will transport pebbles one inch in diameter, and one of two miles per hour pushes along the bottom slippery stones of the size of an egg. Now, as three miles is the maximum speed of any British river, and as a two-mile current cannot propel stones larger than an egg, no British river could transport such boulders as encumber our drifts. And as there are no Victorian rivers which exceed the swiftest British rivers—the Tay, for instance—in the strength and speed of their currents, these boulders must, in an equal degree, be beyond their powers also. But if we suppose that the Victorian rivers were, in late tertiary times, much larger and swifter, so as to equal the swiftest known streams, would they even then be able to create these conglomerates? I think not; for whatever speed our rivers may have had down to the foot-hills, they could not have run swiftly across the flat plains, and these deposits are found far out upon them, as far away as the Murray banks at the Campaspe, and even out on the Darling. These vast plains have at the outside a slope of two feet in the mile, and the Murray, between Albury and Echuca, falls less than one foot (B. Smyth's *Goldfields*, p. 206). What evidence have we that such a small incline could endow a river with the power to transport, however slowly, these heavy conglomerates for long distances across wide plains? Absolutely none that I can discover.

If we turn to mountain torrents as an efficient cause, we find that they may have for short distances, and during brief periods, a speed of from 18 to 20 miles per hour (Geikie's

Text Book, p. 363), and that they are the most powerful fluvial agents known. But they lose their power when they leave the mountain side, so that their agency will not avail us to explain the occurrence of boulder deposits out on the distant plain, or far down gentle valleys.

Nevertheless, as many of our conglomerates occur amongst the hills, we will see what may be the precise nature of torrential action.

On the coast of the Mediterranean, between Toulon and Genoa, the Alps rise almost sheer from the beach, and a number of streams descend through steep mountain gorges and plunge into the sea. For eight months in the year their beds are dry, and during four months the snow waters come down in tumultuous torrents, spreading out fanwise directly they reach the mountain foot. No water-power of greater force per volume than these streams show is known; and yet, with all their force they are unable to keep open their own channels. As the flood widens out on the short, flat coast-strip, it weakens and drops its load. All that enters the ocean is sand and mud, with some lime in solution. A mass of shingle lines the strand.

Every year, after the snow waters have ceased to flow, the Governments of France and Italy have to spend much money to clear the coast road of the bouldery rubbish which these torrents leave behind them. The same phenomena are repeated wherever mountain streams reach the level lands below, for the boulders come to rest directly the torrential character is lost (Lyell's *Prin.*, Vol. I., p. 491). Therefore, if our conglomerates were the product of torrents, they would occur in fan-shaped deposits of limited extent, which is certainly not the case; for, on the contrary, our boulders straggle all over the country in irregular streaks, sometimes fifty miles long.

If we can suppose the above objections to the fluvial origin of the boulders to be explained away satisfactorily, there yet remains another difficulty in the way of its acceptance. This lies in the fact that the violent nature of this mode of transport is such that the boulders would be ground down into gravel, sand, and mud long before they could reach the distant points at which we find them. Professor Geikie states that granite blocks lose 40 per cent. of their bulk by the time they have travelled the first fifteen miles, although the rate of wear is less afterwards (Geikie's *Text Book*, p. 372). Therefore, if we could suppose the motive power to be available, still the boulders would be reduced to pebbles while they were in the act of being conveyed between the ranges and the Murray. And yet great boulders, which must have travelled long distances, abound in the Murray bed, at the Campaspe junction, and elsewhere (Hodgkinson "On the Geology of the Inter-Mitta-Mitta and Campaspe," *R. S. T.*, Vol. I.).

Surely their wide distribution requires some other agency than that of flowing water. If, knowing as we do that the sea covered these plains not long since, we seek it in the ocean, we still fail to find any evidence that its waters could have formed these deposits. The transport power of the ocean is very limited. Where very strong currents prevail strips of boulders occasionally line the strand, but they never move seawards, and only during storms do they travel along the coast at all. If a sea margin is encroaching on the land these deposits are in time left out at sea, and in this manner they may acquire a travelled appearance. But they lose their size, as they pass through the surf, by getting ground down. When Darwin found Patagonia buried under a superficial stratum of such materials, he at first imagined that the boulders might be products of the ocean, and he tested the neighbouring seas to ascertain if they were similarly boulder-strewn. Careful soundings showed him that the boulders were always ground into pebbles before they left the surf. At a distance from the shore of three miles they were never larger than a walnut; at seven miles there were none larger than a filbert, and at twenty-two miles out they had been reduced to a coarse sand, the grains of which were not larger than one-tenth of an inch in diameter. And he found that throughout this width of littoral the diminution in size of the stones was gradual (*Geological Notes on South America*, p. 16). We may therefore dismiss the ocean from our minds, as far as this deposit is concerned.

Upon a review of all the circumstances, it appears to me that the sculpture and distribution of boulders is not, in the main, due to water-power, and I am acquainted with only one agency which is capable of doing the work, and that is ice.

The power of ice is unquestionable. Frost breaks up rock surfaces rapidly, and wedges off masses. The surface ice of frozen streams destroys the river sides. Ground ice, or anchor ice, as it is sometimes called, envelopes the boulders and gravel of the stream bed, lifting them up, and floating them along with the current. In this manner streams may rapidly transport material that the current, unaided, could never stir. Glaciers carve into the mountains, and scoop valleys and lakes out of stony plains. They level hills, and fill up valleys with the spoil. They carry *débris* as far as they go, and then drop it in huge mounds; or, if they are situated on a water edge, they transfer it to bergs and floes, which distribute it still more widely. As a transporting agency, ice is the most powerful known. In the present age its potency is restricted by the moderate climatic conditions prevailing. But there have been periods when very different conditions held sway, and this agent was then free to operate upon a grander scale, and over vast regions of the earth now outside its influences. The zones, now temperate, show land surfaces teeming with the evidence of its vast mechanical powers.

If Victoria has ever had a climate which would supply the ice required for boulder transport, we ought to find some evidence of the fact besides simple boulder washes.

The characteristic signs of intense ice action consist in rock striæ, or scratches, more or less parallel; in glacial lake basins, in rounded rock surfaces, and hills of flowing outline; in the *débris*, the litter, the refuse of their work, strewed sometimes in heaps, and at other times spread out in sheets of clay, sand, and rock fragments. Lastly, we have the loëss, or loamy secondary product—the sifted-out grindings of the icemill, washed out of the coarser stuff by the snow waters, and swept down the slopes in muddy torrents to be dropped quietly in the still reaches of the flooded plains, and in the shallow sea margins, as a mantle of fertile alluvium.

Let us now see whether any such traces of glacial action —which can be assigned to post-miocene times—have been discovered in Victoria.

I will preface the evidence I shall produce by admitting that the indications, if viewed separately, are ambiguous; but if they are regarded all together they show such a converging trend upon the part of a large number of small facts that they carry conviction; for they all, to my mind, point toward a period of great climatic extremes not far remote in a geological sense.

Taking rock markings first, their occurrence here has been questioned by many. I do not claim to have seen any myself, but Mr. Wm. Lee, a practical miner of experience, assures me that he has seen ice striations near Wilson's

Promontory. The Rev. W. B. Clark reports ice markings on the mountains of New South Wales, and the Rev. Julian Woods, in his *Geological Observations in South Australia*, writes (p. 20) that "it seemed to him that there were very distinct marks of snow and action of glaciers" on the flanks of Mount Lofty, near Adelaide. Mr. Gavin Scoullar read a paper some time since before the Adelaide Philosophical Society, in which he describes a boulder drift at Hullett's Cave which rests upon a well-striated pavement of rock (*P. S. T.*, 1877-79, p. 65).

Professor Tait, in an address to the same society, describes smooth, striated, grooved rocks in the bed of the Inman, Cape Jarvis (*id.*, Vol. LXV.). Selwyn had seen these last-named rocks long before, and he tells us that "the direction of the grooves and scratches is east and west, in parallel lines," and he adds—"I do not think they could have been produced by the action of water. They strongly reminded me of the similar markings I had so frequently seen in the mountains of North Wales" (Selwyn's *Notes on South Australia*, p. 4).

Professor Tait also describes smoothed, grooved, striated rock surfaces, and morainic *débris* of angular blocks of red granite, gneiss, hornblende, and quartz, at Black Point, Holdfast Bay; and he points out the circumstance that the nearest source from which these rocks could have been obtained is thirty-five miles distant. All these South Australian indications of ice are said to be of pliocene age (*id.*, Vol. LXIV.).

I am not aware of the occurrence of any other examples of rock striæ, within South-eastern Australia, of post-tertiary date. There are others to be found, as those of the Lederderg, but they are believed to be of miocene age.

The scarcity of such evidence is accounted for easily in several ways. For instance, rocks differ in their capacity to retain markings. Limestone, serpentine, and clay ironstones polish well, and preserve their striæ long, while sandstones streak faintly and weather quickly. All the softer rocks, and those which are highly jointed, break up rather than polish (*Great Ice Age*, pp. 16-21). Further, those which are impregnated with salts decay quickly. Now, our silurian slates, sandstones, and shales are loaded with iron oxides, and are upedged; while our recent marine sandstones abound in the chlorides of magnesia and soda. Therefore our rocks are to a large extent ill-suited either to receive or to retain ice scratches. Most persons must have been struck by the rapidity with which the finer chisel marks upon the stone faces of our public buildings and the lettering of our monuments and tombstones have lost their sharpness of outline, for, short as is the time during which they have been exposed to the weather, they have begun to decay. But even the hardest rocks will lose their markings if they are not covered in some way; and in a newly-settled country any marks so overspread as to be preserved might long lie concealed. Again, thin ice does not leave behind it striæ, moraines, or till. Such are the products of massive ice alone, and to nourish such high land is required. Now, Victoria has not a large area of mountain land; the scope of such ice action would be restricted to its neighbourhood, and there would be but little use in searching for its traces over the lower and larger area. Frigid as is Siberia's climate, its flatness is such that she cannot show any of the deeper traces of glaciation, and yet snow and ice cover the country during large portions of the year (*Great Ice Age,* p. 555). Near the Rocky Mountains of North America there is a large patch of country quite bare of such traces, while all around it they abound (Geikie's *Text Book*, p. 899). This absence is due to some local peculiarity, and not to the non-occurrence of a glacial climate, and therefore the absence of such evidences is not conclusive as against the occurrence of a glacial climate. Bearing all the circumstances to which we have adverted in mind, we ought not to wonder at rock striæ being scarce, but rather we might feel surprised that any should have been preserved.

We have, in the next place, to look for any ice-scooped lake basins, which are only striæ on a larger and deeper scale. These, also, are infrequent here.

Lake Omeo seems to be fairly identifiable as one. It occurs on a rocky plateau 3000 feet above the sea level, and is three and a half miles long by one and a half broad. It has no outlet, and appears to have been hollowed out of the rock. I understand that Mr. A. W. Howitt attributes several other lakelets in this district to ice action.

Several of the Tasmanian lakes are of glacial origin, having been ice-dug out of solid stone. Such an one is the Great Lake, twelve miles long, and Lake St. Clair, ten miles long (Wallace's *Australia*, p. 242).

When considering the existence amongst our hills of glacial lakes, we must remember that glaciers fill up, as well as scoop out, these rock basins, and that they often leave finally a plain of deep alluvium to replace a rocky floor removed. Lake basins thus obliterated are hard to identify, and may be overlooked easily. Some such levelled-up mountain tarns are known to exist here. Mr. J. Stirling has recently described one in a paper contributed to this Society entitled the "Physical Features of the Australian Alps." In it he writes thus:—"Occupying the valley of the Livingstone Creek since the lower silurian rocks became metamorphosed into the present crystalline schists were a series of ancient lakes or tarns, into which, by the breaking up of the ancient lava flows, masses of igneous boulders became deposited. Subsequently the gradual wearing down of the metamorphic schists, with their associated auriferous quartz veins, filled up these ancient lake beds with a deposit of boulders and auriferous gravels. Ultimately the Livingstone Creek . . . eroded a channel along its margin, leaving the deposited gravels, with their underlying false bottom of igneous boulders, literally high and dry above the bed of the latter stream" (*R. S. T.*, 1882, p. 106). Now, there can be but little doubt that it was the glacier which scooped out this lakelet, and also broke up the *débris* with which it is filled. As the ice melted a watery flood swept down the glacier rubbish from above, and levelled it to the brim. Then the surplus *débris* passed on to fill up other pools lower down. The mountain creek which succeeded to the glacier eventually cut through the formation and revealed the story.

Brough Smyth records that there are amongst the Gippsland hills many level tracts of alluvium, from 200 to 300 acres in extent, surrounded by precipitous rocks and situated at the junction of streams. I think that these will eventually prove to be similar filled-up tarns of glacial origin (B. Smyth's *Goldfields*, p. 12).

In the watershed of the Ovens there are hollows in the granite, now filled up with sedimentary strata, which may also be numbered amongst the traces of ice erosion in Victoria (B. Smyth's *Goldfields*, p. 83).

If we step down from the mountains we shall see that our miners have discovered, beneath the smooth wide plains and the softly swelling rises which diversify them, an ancient land surface of very different contour. This concealed earth-surface is composed of bare silurian rock, which has been sculptured by natural agents until it is ribbed and guttered like the fluted face of an old clay cutting, but with this great difference, that cuttings are generally steep enough to create the waterflow required to carve them, whereas the plains we have in view are inclined at very low angles, and therefore are traversed only by sluggish streams. The corrugations of this rocky surface are masked by an accumulation of clay, sand, gravel, and boulders, and in part by intercalated lava flows. These gutters trend from the Dividing Ranges at a broad angle, those to the north dipping under the Murray at a depth of from 300 to 400 feet from the present surface, and those to the south disappearing beneath the recent alluviums which swathe the foot-hills (*G. S. V.*, Vol. VII., pp. 80, 81). These gutters are the "leads" of the miner; and our present interest in them lies in discovering the means which eroded them. Our choice of agencies lies between water and ice, and if we incline towards the latter it is because we see that these leads traverse country which has but a slight fall, and because we see that they have been filled up by the "spoil" characteristic of ice action. I believe that it was the ice plough first, and flowing ice-water last, which furrowed them and then filled them up.

The next product of glaciation which I shall point out to you is the smooth-swelling rock surface which tells of massive ice moving slowly across the country and planing down all prominences into flowing outlines. Such contours we have on a large scale—undulating, rounded hills,—a constant feature of all Victorian landscapes; but of the minor form —the *roche moutonnée*—we have no example that I can hear of in Victoria. We have to visit South Australia to secure the missing link. Professor Tait has described the occurrence of dome-shaped rocks at Kaizerstühl and Crafers, two localities in that colony (*P. S. T.*, Vol. LXIV.).

We therefore come to the last feature of glaciation—to the rubbish which has been planed and ground off; to the clays, the sand-drifts, the gravel beds; to the cemented conglomerates and the loose boulders.

All these we have in abundance, filling up the hollows, crowning the rises, terracing the mountains, and sometimes, capped with basalt, standing out on the open plains all alone, solitary outliers, the remnants and measure of eroded plateaux.

Before we describe the alluviums in detail it will be a guide to us, in discussing their origin, if we remember the characteristics of well-attested ice *débris* in Europe and America.

Jas. Geikie in his work, *The Great Ice Age*, speaks of them as consisting of sheets of "sand, gravel, and widespread deposits of clay" (p. 4); also, as "a stiff sandy and stony clay, varying in colour and composition, according to the character of the rocks of the district in which it lies. It is full of water-worn stones of all sizes, up to blocks weighing several tons" (A. Geikie's *Text Book*, p. 161).

Let us compare these descriptions with the following:—

Mr. R. H. Stone, mining surveyor, writes as follows of certain deposits in the Ovens:—"The bed-rock is very uneven, consisting principally of soft yellow sandstone with veins of slate intermixed, and occasional bands of hard blue stone (metamorphosed slate). . . . The auriferous drift consists of heavy water-worn gravel and sandstone boulders, slightly intermixed with quartz, and having here and there layers of ironstone cement. In some places there are enormous boulders of bluestone rock, sometimes weighing many tons. The drift is from 3 to 50 feet in depth, and is covered with red loam. . . . Some portions of the drift are very hard and difficult to work, and others so loose as scarcely to require the use of the pick" (B. Smyth's *Goldfields*, p. 84).

The following example occurs in the Buninyong Estate Claim, near Ballarat, which is thus described:—"From No. 8 shaft the drive at 410 feet suddenly entered a mixed mass of clay, angular fragments of silurian, from a small size up to several feet in diameter, angular quartz, and dense blocks of exceedingly dense lava, piled one on another, or isolated through the mass. . . . A few isolated nests of gravel were encountered" (Lock's *Gold*, p. 673).

Mr. O'Farrell, chairman of the Maryborough Mining Board, reports that on a hill two and a half miles from that town the depth of sinking was from 16 to 24 feet, "through hard cement mixed with large white boulders;" and also "that at Majorca the sinking was 85 feet, through stiff clay, gravel, and cement. The washdirt was white gravel intermixed with white boulders" (B. Smyth's *Goldfields*, pp. 97, 98). Similar examples are so numerous that the only difficulty has been to decide which to select.

To show how widely this deposit is distributed, I will give three other instances. On the Wimmera, near the edge of the mallee country, the wells pass through marly clay, sand, shells, gravel, and boulders, and then bottom on a rotten granite. At Kiandra, in New South Wales, the sinking shows the following strata:—Surface soil with floating boulders of basalt and large blocks of cement, 7 feet; clay, 20 feet; lignite, 18 feet; sand, 3 feet; fine drift, 65 feet; coarse drift, with big boulders of quartz, jasper, and ironstone, and containing gold, 6 feet—total depth, 119 feet (*Gold,* p. 510).

At the Field River, in South Australia, there is a deposit of clay and rough blocks of stone piled up indiscriminately (*T. P. S.,* Vol. LXIV.).

At Gnomery, beyond the Darling, and Fort Burke a well has recently been sunk 192 feet, through sand, clay, and silt. At the depth mentioned a layer of granite boulders and pebbles was encountered.

These deposits answer closely to the typical till of the Old World; but if we examine the great bulk of our alluviums we shall notice in them only a general resemblance. We discover similar materials, but they are more assorted and stratified. Our deposits are those of till which has been rearranged. Massive ice first turned the glacial drift out of its grinding mill; then melting mountain ice, in torrents, tumbling from level to level, stripped the till from hill flank and valley side, swept it into the still reaches of the flooded lowlands, and thence carried it out into the shallow sea which occupied all the plains. In these quiet waters the materials were roughly assorted and spread out. In this operation the pre-existing features of the country were completely obliterated by the *débris* shot upon them.

Geologists have described similar operations in other countries. James Geikie, in his work, *The Great Ice Age,* remarks that "the disappearance of a *mer de glâce* was doubtless accompanied by excessive floods;" and further, that "we might expect to meet with evidences of such floods in the presence of more or less tumultuous accumulations of gravel, shingle, and boulders. . . . This drift sweeps up and over considerable hills, and occurs on the tops of plateaux and on the dividing ridges of separate river basins. . . . That the drift is not now more continuous is due to subsequent erosion" (pp. 264, 265).

As an illustration of the water-power set free during the decline of a glacial period, the same author records that, while America was passing through that ordeal, the ice-waters augmented the Mississippi until its average width was seventy-five miles where it is now a bare half-mile broad (*id.*, p. 475, and *Lyell's Principles,* Vol. I. p., 441).

To return to our own formations, we must not imagine that when once these leads were buried out of sight they remained for ever undisturbed. On the contrary, they have been scooped out and refilled repeatedly.

Captain Couchman describes some hills at Fryer's Creek as being covered in a "most erratic manner by a gravelly wash, which is as plentiful on the tops and flanks of the hills as on the floor of the gullies" (B. Smyth's *Goldfields,* p. 158). A. W. Howitt reports gravel beds which occur upon the Delegete at from 500 to 600 feet above the river (B. Smyth's *Goldfields,* p. 118), and also drifts of rounded quartz between the Clifton and Nicholson. "These not only cover the hills as surface, or form beds in the stream, but also, in places, constitute 'made' hills" (*Gold,* p. 681).

Ainsworth (mining surveyor) gives a description of a drift of slate and granite boulders and clay on the Nevermind Spur, Wood's Point, at an altitude of 1200 feet (B. Smyth's *Goldfields,* p. 87); and Hodgkinson, in a paper "On the Inter-Mitta and Campaspe Geology," mentions the occurrence of recent alluviums of water-worn schist, quartz, and slate on granite hills near the Campaspe mouth, which drifts, he says, "are not only at a considerable elevation, but must have been brought from very far-distant sources" (*Phil. Ins. T.,* Vol. VI.).

Krausé reports similar deposits of older pliocene date on hills near Stawell (Lock's *Gold,* p. 651).

From the condition of these alluviums, we can picture a time when the sea was receding from till-covered plains. As it withdrew the land surfaces became veined with creeks and rivers. These, as they wound down the gentle slopes, slowly scoured out the soft materials until, in time, gravel-capped ridges separated the several watersheds.

Meteoric conditions approximating more and more closely to those of this age then succeeded, and must have held sway for a long period, perhaps 80,000 years (Croll, *C. and T.,* p. 325). Ordinary fluvial action has, therefore, been the last and longest modeller of the surface. It has given the finishing touches, and, of necessity, all the superficial appearances indicate the sculpture of flowing water. The scour of the stream has dimmed the traces of all prior agencies; but if by the aid of experience gathered from other countries which have been glaciated we can look through the lighter outlines sketched on the rocks and sediments by aqueous action, we shall discern beneath them the touch of the heavier hand and the sharper chisel of frost and ice and snow.

Therefore we are stimulated to inquire whether the sister sciences can throw any side-lights upon the problem of the post-miocene glaciation of Victoria.

It appears to me that very valuable aid is available from these sources.

II.

Recent investigations have established the fact that the earth's climate, so uniform in character within historical times, varies very considerably if we take long periods into account. The climate known to man has been shown to be a mean between two extremes of heat and cold which have prevailed during previous epochs.

Dr. Croll has investigated the subject very fully, and the conclusions which he has formed have been accepted by such men as Archibald Geikie, the Inspector-General of the Geological Survey of Great Britain, and by Sir William Thomson.

He has shown that the earth's climate at any period depends upon a complex arrangement of circumstances. It is, of course, in the first place, dependent upon the amount of heat sent to it by the sun; but the effect of this, or its amount at any particular time, is modified by the form of the earth's orbit at that time, by the position of the earth in that orbit, by the precession of the equinoxes, the obliquity of the ecliptic, and greatly by the distribution of snow and cloud on either hemisphere. All these conditions are inconstant, although they change but slowly. And as their rates of alteration vary they sometimes coincide and augment their effects, whilst at other times they neutralise each other's influence more or less.

The earth's orbit varies from age to age. At this moment it is losing the elliptic form it had not very long since, geologically speaking, and it is becoming more and more circular. The limits of its variations are known. Fourteen million miles is the highest eccentricity to which it attains, and its lowest is about half a million. At the present moment its variation from a true circle amounts to three million miles. The result of this inconstancy is that the seasons, apparently so equally distributed throughout the year, are variable in length from epoch to epoch. The present eccentricity gives to us in the Southern Hemisphere a summer half-year seven days shorter than our winter half-year; but there have been periods when the difference amounted to thirty-six days, and, on the other hand, times when the difference was only forty-eight hours.

Indirectly the temperature of the earth is greatly affected by these variations in the length of the seasons; and when the winter of either hemisphere is prolonged by thirty-six days the earth absorbs less heat than it does now by one-fifth part (Croll, *C. and T.*, p. 56). Whenever the orbit attains to a high degree of eccentricity the climate of one hemisphere becomes intensely cold, while the other grows hot, moist, and winterless. The one which cools down is the one which has wintered in aphelion; it finds itself furthest from the sun just when it most needs its warmth. The other hemisphere enters on its warm season as it is approaching the sun, and it is heated up excessively in consequence.

Owing to the effects of precession, each hemisphere exchanges places and climates with the other about every 10,500 years, so that this period is the term during which either hemisphere can experience extreme heat or extreme cold. But the orbital eccentricity may last many times longer, and while it lasts the earth's climate will be marked by remarkable oscillations of temperatures between the two hemispheres.

The last epoch of high eccentricity commenced 240,000 years ago, and, having lasted about 160,000 years, came to a close 80,000 years since (Croll, *C. and T.*, p. 325). During this epoch each hemisphere experienced about seven oscillations of climate, passing through seven glacial and seven sultry periods. The winter of one hemisphere was always between eighteen and twenty-six days longer than its summer, while the other hemisphere had its summers from eighteen to twenty-six days longer than its winters. In consequence of this the temperature of the cold hemisphere was lowered from 29.5° to 37.7° F. below the present winter temperature (*C. and T.*, p. 320).

But the full effect of these changes was attained indirectly. The long warm period in one hemisphere caused its polar ice-cap to disappear after a time, and as it melted off one pole it accumulated around the other. Thus the earth's centre of gravity became disturbed; it shifted towards the loaded pole, and, as it moved, it drew after it the fluids of the globe—the sea, the plastic nucleus, if there be one, and perhaps the atmosphere. As the ocean readjusted itself to the new centre, by heaping up its waters around it, the low lands of that half of the globe were swamped, whilst the sea drained off the shallower littoral of the other, converting large areas of sea bottom into dry land.

Dr. Croll goes further, and taking the present rate of sub-aerial denudation as a measure of time, shows that there are excellent grounds for believing that the period of eccentricity just referred to corresponds with the last glacial epoch in the Northern Hemisphere, which occurred towards the close of the tertiary and the commencement of the quaternary periods, that is to say, during post-miocene times.

But if the Northern Hemisphere passed through a glacial period about that time, the Southern cannot have escaped; and the only question to be discussed to-night is whether Victoria was or was not within the range of its rigours.

Now, geologists have determined the range of glaciation in the Northern Hemisphere so well, that their conclusions will afford us great help in ascertaining the range of glaciation here.

Croll and others find that the polar ice-cap must have been two and a half miles thick at the least, and that it was probably vastly more, perhaps as much as twelve miles (*C. and T.*, pp. 377-81); that the ice was two and a half miles thick in Canada, and 2000 feet deep over Scotland (*C. and T.*, p. 452). One vast ice-sheet covered all Europe down to the latitude of the Thames; while far southward of 52 degs. N. latitude every mountain had its glacier system. The equatorial margin of this ice-cap was as irregular as an isothermal line on a chart, and in places it overlapped latitudes corresponding to that of Melbourne (*Great Ice Age*, p. 457). Therefore, there is nothing unlikely, in itself, in the statement that Victoria has been glaciated; and its probability is increased when we remember that all the lower lands of Australia must then have been submerged, whereby the northern interior, which now serves as a warming pan to our atmosphere, was exchanged for cool sea-water; that the north-west anti-trades would then be stronger and moister, and the south-west Antarctic Ocean drift would then be stronger and colder; that then every zone of temperature must have been shifted equatorward at least 10 degs., so that the wet west winds which now circulate below 40° S., and which feed the glaciers of New Zealand and Patagonia, would then blow up to 30° S., soaking with rain or mantling with snow the islands of Australia. For then Australia, partially submerged by the ocean rise, was an island, shaped like a jack-boot, with the Darling Downs for its uppers, the Howe for its heel, the Grampians for its toe, and the Adelaide ranges for its Sicily; while its long rocky length lay north and south, right athwart the course of the chilly, moisture-bearing winds.

In the other hemisphere the edge of permanent ice moved down from 77° N. to 50° N., or an advance of 27 degs. If a similar advance was made in this hemisphere the ice barrier must have been in 43° S., which is the latitude of Hobart. Nor is there anything extraordinary in this supposition, for New Zealand has even now, in the same latitude, a glacier which descends within 700 feet of the sea; while South America has, in 46° S., glaciers which dip into the sea and shed icebergs. If, therefore, the ice-barrier were then as near to us as 43° S., our coast would have been cumbered with bergs and floes, and the mountainous island of Australia must have been as cloaked with ice and snow as the Georgias are to-day. Australia might not be high and large enough to nourish a true continental ice-sheet, but every range would have its confluent glaciers, whose projecting feet might plough up the shallow foreshore.

According to Croll's calculations there must have been a lowering of the temperature, which would vary between 29.5° S. and 37.7 E. (*C. and T.*, p. 316). The present mean temperature of Victoria is 58° F. If we take this as a standard, and deduct the lower amount, the result will give us 3° below freezing point as the mean temperature of Victoria during the glacial epoch; and if we make our mean winter temperature, which is 49°, our standard, then the temperature would have a mean of 12° below the freezing point, and that of Sydney would be about 7° below—that is to say, the temperature would be that of South Greenland in winter time. We must not forget that at this time there was a lofty sandstone plateau of miocene age where our Dividing Range now stands, and that these highlands probably had an altitude of at least 2000 feet greater than the present peaks. The glaciers these extensive chilly heights would breed may have been the main factors in filing down their even crowns into the existing series of sierras (Howitt, *R. S. T.*, Vol. XVI.). The *débris* of these peaks may have supplied the material to build up the sandstone plateaux of Central Australia, whose flat surface of cretaceous age was in those times submerged, and which, it is probable, was covered with brackish ice-waters of shallow depth, loaded with sediment, running northwards in strong currents. Let us see what geological evidence we have to countenance these theories.

It will be admitted, as a fair inference, I do not doubt, that if the other lands situate in similar latitudes in this hemisphere can be shown to have passed through a glacial period about the close of the tertiary period, Victoria cannot have escaped the same experience.

If, then, we turn to New Zealand, we shall find the geologists of that colony recording the existence, during the epoch in question, of glaciers so much greater than the present ones, that, where the largest to-day does not exceed from 15 to 18 miles in length, there then was at least one 112 miles long (V. Haast's *Geo. of Canterbury,* p. 385).

In South Africa we find evidences of a similar climatal condition. All over British Kaffraria and Natal—that is, between 28° S. and 34° S.—dome-shaped rocks, enormous erratics, unstratified boulder clays, and conglomerate beds are abundant. There are ice-grooved rocks and boulders, the latter being found in auriferous leads at the Moonlight Diggings; and also long, winding kames running up the valleys (*G. S. J. Stow,* 1874, pp. 588-658; XXVII., p. 535; and XVIII., p. 8).

It will be noticed that these occur nearer to the equator than is either Sydney or Bourke.

In South America we find glacial drift at low levels up to 18° S., and Agassiz reports similar deposits in Brazil. David Forbes saw deeply furrowed rocks and other characteristic evidence on the Cordilleras within the tropics, and far below the present snow-line (*Gold,* p. 216). Darwin saw immense moraines in Central Chili (*Or. Species,* p. 335), and also widespread deposits of boulders, gravel, and clay, up to 1400 feet above the sea level, in the interior of Patagonia (*Geo. Obs. on South America,* pp. 10-19), and he assigns them to pliocene or pleistocene times.

I think that these facts should fairly suffice to establish the occurrence of a glacial climate throughout the now temperate regions of this hemisphere, and during post-miocene times. If this be so, it is hard to see why Victoria should have escaped the same experience; and I think that we are entitled to this opinion whether the local evidence is accepted as sufficient or not.

But there is another of the sciences which we can call in to aid us in fathoming the problem.

If we turn to the natural history of this hemisphere, we find that the present geographical distribution of plants and animals absolutely requires a glacial period to account for its anomalies.

Darwin is emphatic enough on this point. He tells us that "we must bear in mind the occurrence in both hemispheres of former glacial periods, for these will account for the many quite distinct species inhabiting the same widely separated areas, and belonging to genera not now found in the intermediate torrid zone. . . . In the regular course of events, the Southern Hemisphere would in its turn be subjected to a severe glacial period, . . . and then the southern temperate forms would invade the equatorial lowlands. The northern forms which had then been left on the mountains would now descend and mingle with the southern forms. Thus we would have some few species identically the same in the northern and southern temperate zones, and on the mountains of the intermediate tropical regions" (*Or. Species*, ch. XII., pp. 339, 340).

When we seek confirmation of these views of Darwin's, we find it. Baron von Mueller reports the discovery of European species of plants upon our mountains, and Dr. Hooker points out that certain peculiarly Australian forms of vegetation now live upon the heights of Malacca, India, and Japan. Further, there are northern forms of fish and seaweed living upon our coasts, although absent from the seas which intervene between Australia and the habitat of the other members of these families.

No naturalist has given more consideration than has Wallace to the distribution of the flora and fauna of this quarter of the globe, and his statements are entitled to attention. If we compare the distribution of our plants, as he describes its occurrence, with the plan of distribution which we should expect to succeed to a glacial and submerged period, we must be struck with the remarkable degree of accord which they present.

If our climate be recovering from a glacial period, as we believe that it is, then all the temperate zones will be moving northward toward the equator, the warmer ones in front, the colder ranked behind. As this occurs the flora and fauna follow them, keeping slightly in the rear; for each temperature as it withdraws from a district has to pull after it the forms of life peculiar to it, and the different climate which follows on its heels cuts off the laggards and stragglers before they fall very far in the rear of the main body. Now, according to Wallace, this process is going on in Australia. He tells us that our tropic flora is wanting in several important tropic families, which are, singularly enough, to be found in our temperate regions. Such are the *Dilleniaceæ, Liliaceæ, Polygaleæ,* and many others (Wallace's *Australia*, 222). The presence of such tropic forms in these temperate regions shows that not long since a tropic climate reigned there, and that it has moved away equatorward faster than the vegetation could follow it. The tropic regions to the north of them, and into which they have not yet passed, is poor in vegetal life, because it has only recently emerged from the sea, and the immigrants from the south, and proper to it, have been slow in coming. Again, such a submergence as we suppose accompanied a glacial period would cut Australia into two parts at least, an east and a west island; and the marked difference between the eastern and western floras accord with such a severance. Out of four hundred and fifty known species of acacia, melaluca, and eucalyptus, not a single one is common to the two provinces. "The large genera common to both sides of the continent are," says Wallace, "wonderfully distinct." (Wallace's *Australia*, 46).

Furthermore, as the retiring tide leaves behind it pools which indicate levels recently attained to, so a retiring temperature leaves in its wake its flotsam and jetsam to attest its former presence in latitudes now behind it. As the temperature of a locality rises, some of its flora and fauna may remain, and yet save themselves from extinction by having access to higher lands. Thus it is that the Antarctic genus *Drimys* still lives far up on the lofty heights of New Guinea (Wallace's *Australia*, 444) and of Borneo (*ib.*, 353), after its congeners have wandered southward some thousands of miles, and that thirty-eight species of European plants are found on the mountain peaks of Victoria wherever they rise over 5000 feet in altitude.

Similarly, as the temperature falls, some plants secure themselves by retreating to sheltered spots, where they survive after their neighbours have either moved on or been destroyed. We have such a relic of torrid times in Victoria in the cabbage-palm, which is found in the warm, moist, and well-sheltered gullies of Gippsland, although outside of these natural hot-houses it is sought in vain until we reach the tropics, now its natural home (Wallace's *Australia*, p. 130). How could this heat-loving palm-tree have marched over the Dividing Ranges into Gippsland, unless a rise in the temperature at some earlier period had favoured the passage?

Again, we must call in glacial influences to account for the disappearance of the huge beasts which tenanted Australia in bygone times.

Wallace tells us that "we live in a zoologically impoverished world, from which all the largest, fiercest, and strongest forms have recently disappeared" (*Geo. Dist. P. and A.*, p. 150), and he connects this remarkable fact with the refrigeration of climate during the glacial period.

Professor Phillips also connects the extinction of the great carnivora and pachydermata with the same cause, while Professor A. Geikie takes a similar view *(Text Book*, p. 894). It must at once occur to every mind that our great marsupials died out early in the quaternary epoch, if not before then. If it was this cold which destroyed the monsters of the other hemisphere, it was probably the same cause which destroyed those of this half also. Their extinction at this particular point of time indicates to us a severe fall in the temperature of Australia.

The next question we shall have to consider is that of secular oceanic oscillation. As we have already mentioned, Croll and others believe that the loaded pole of a glacial period shifts the centre of gravity and pulls around it the waters of the ocean. Taking his figures as a basis, an Antarctic ice-cap extending only 55° S. latitude, and having a slope of only half a degree, would cause the sea level to rise 1100 feet at the South Pole, and about 900 feet in the latitude of Melbourne (Croll, *C. and T.*, p. 389).

Now, any such a rise within the period we are discussing would leave behind it traces which we could recognise; and as a glacial epoch and land submergence are connected together in nature, the evidence which establishes the occurrence of the one may be brought in to support that of the other.

A rise of 900 feet on the part of the ocean would convert Australia into a long, narrow, mountainous island, with an archipelago to the west of it, the former representing Eastern and the latter Western Australia.

Now, we have in Victoria marine deposits of post-miocene age up to and over the altitude of 1000 feet.

Krausé, in his report upon the Otway Ranges, describes extensive marine deposits of pliocene age up to 1200 feet above the sea (*Geo. Sur. Rep.*, 1874, p. 103); and in another report he has described horizontal tertiary sea beaches on the flanks of the Grampians at an altitude of 900 feet (*id.*, p. 124), and another near Ararat at 1100 feet (*G. S. R.*, Oct., 1874).

At Creswick there are pliocene marine deposits at elevations which vary between 1420 feet and 1720 feet (Lock's *Gold*, p. 931).

A. W. Howitt has described similar tertiary deposits near Mount Taylor, at an elevation of about 600 or 700 feet (B. Smyth's *Goldfields*, p. 123).

At Portland we get further evidence. The beach cliffs are of a kind of pliocene chalk, which is known as *Globegerina ooze* because it is full of the foraminifera *Globegerina bulloides* and *Orbulina universa*, which do not live in waters of less depth than 1500 to 1600 feet. They are a well-determined form of deep-sea life. To expose these deep-sea beds above water the sea level must have fallen 1500 to 1600 feet within pliocene times, and this amount of alteration in the relative level of sea and land fairly agrees in degree with the evidence from the mountains (Woods' *Geo. of Portland*, pp. 14-16).

Again, on the flanks of Tower Hill, near Warrnambool, a well was sunk 123 feet. The first 63 feet was through volcanic ash, and the last 60 feet was through clay. At this depth the skeleton of a dingo was found. The dingo is believed to have been introduced to Australia by man; and in any case it is a late introduction. Yet after it died the ocean covered that part of the country, and had time to deposit many feet of sediment before it retired (*Q. J. G. S.*, 1857, p. 227).

The Rev. Julian Woods has described a tertiary marine limestone on Tapley's Hill, near Adelaide, which occurs 1000 feet above sea level; and another observer, in a paper contributed to the Adelaide Philosophical Society (*A. P. S. J.*, 1877-9), states that there are traces of submersion to 800 feet in late tertiary times.

Western Australia has risen above the waves since the pliocene era closed, but I cannot ascertain that any measurements have been recorded.

As to New Zealand, Hutton declares himself strongly convinced that the Canterbury Plains, now 1700 feet above the beach, were under the sea at the commencement of the pleistocene period (*Geo. Sur., N.Z.*, 1873-4, p. 58); and, although Dr. von Haast disputes this conclusion, it harmonises with the other evidence. Besides this, the latter geologist admits that New Zealand was submerged to a considerable depth during pliocene times (*Geo. of Canterbury*, p. 373).

From South Africa we learn that pliocene shells are found in deposits high above the sea level throughout Kaffraria, but the exact height is not given (Stow, *Q. J. G. S.*, XXVII., p. 544).

Turning to South America, we find that on the east coast, from Cape Horn up to 33° S. latitude, there are old sea margins at seven different heights, the highest being 1400 feet above sea level, and these are of pliocene or later age. Darwin is of opinion that during this period this part of the country was an archipelago, a conclusion strangely similar to that which we have already arrived at concerning Australia at about the same time (*Geo. Notes S. Am.*, p. 10).

On the west coast there are margins up to considerable elevations; but their evidence is unreliable owing to the volcanic disturbances on that coast which have interfered with the levels.

This is the evidence that I have to offer in favour of the view that within post-miocene times Victoria has been dipped beneath the waves. The exact depth to which she sank it is difficult to fix, for there have been several rises of the sea, and each should have left its mark. As it is unlikely that any two were alike in height, and as most of the traces have disappeared, those remaining probably represent the relics of not one, but of several rises. And further than this, there are slow earth movements which ought to be taken into account, if they can be ascertained, when we endeavour to fix the exact amount of alteration in the levels. The broad fact remains, however, that the geological evidence fits still further into that drawn from so many other sources, and it points to a general submergence of the land throughout the latitudes south of 33° S.

The last evidence that I shall submit to you is that of the seven or eight warm periods which were intercalated between the seven or eight cold ones which occurred during the last epoch of high eccentricity. We saw that each of these periods had a length of a little over ten thousand years. The cold periods have left behind them many inorganic traces of their occurrence. The warm, interglacial periods, however, produced a luxuriant growth of vegetation, and the remains of this are fairly plentiful.

Thus, there are the fossils of the Haddon lead, which Mueller declares to be indicative of a hot, humid, equable climate during the newer-older pliocene period, and these are closely adjacent to a deep boulder bed, indicative of glacial times, the proximity of which tells us of a quick succession of climatic changes.

At the mouth of the Cumberland Creek, near the Otway, there is a lignite deposit, the product of warm, moist, equable times, closely overlain by a conglomerate of sand, gravel, and huge boulders, relics of the other extreme (*Geo. S. Rep.*, p. 96). Similar deposits, in close juxtaposition, occur in considerable numbers throughout the colony, and notably in the superficial alluviums of Gippsland (Selwyn, *Phy. G. Vict.*, p. 79). On the heights of Kiandra we have lignite intercalated between conglomerates of pliocene age.

Baron von Mueller has discovered evidence of these climatic fluctuations in three complete changes in the character of Australian vegetation, all of which have occurred since the commencement of the pliocene period. The fossil remains show that when the older pliocene deposits were being laid down this country had a lauraceous flora. With the newer pliocene this disappeared, and in its stead plants of the meliaceous order became in the ascendant, and had associated with them a richly tropic flora. This may have been the period which yielded the palm frond discovered fossilised in Tasmania (*Geo. S.*, Vol. II., p. 24); and our cabbage-palms, in Gippsland, also may trace back their introduction to this era.

With the close of this period meliaceous plants disappear completely from this continent; the tropic forms move northward; and in pleistocene times myrtaceous plants come upon the scene for the first time, and eventually give to our scenery the peculiar and marked character that it now has (*G. S. Vict.*, Vol. II., 29).

When we reflect upon these three entire and rapid changes in our vegetation, we can find no explanation that will account for them as the glacial epoch will, with its climatic fluctuations, its sea oscillations, and its frequent breaking up and reuniting of our continent.

But the fact that fossils indicative of warm temperatures have been found in formations of pliocene and more recent times has been used to prove the impossibility of a glacial epoch having occurred in Australia. We must, therefore, devote some consideration to the arguments and evidence of those who hold views which differ from those set forth in this paper.

III.

The Rev. Julian Woods, in the year 1867, contributed to this Society a paper designed to prove that there had never been a glacial period in Australia within tertiary times.

He based his conclusions upon the following grounds:—Firstly, because our early tertiary fossils have a tropic facies; secondly, because our miocene shells are identical with species now living under the equator; thirdly, because South Australian pliocene shells are also identical with tropical species; fourthly, because a Tasmanian pliocene formation has been found with a fossil palm in it; fifthly, because the quaternary shells of Western Australia present a tropic aspect.

Upon the strength of such evidence he decides that Australia has not experienced a glacial epoch within tertiary times, but that, on the contrary, the climate was very warm in early tertiary times, and has been cooling down ever since.

In criticising this evidence we have a great advantage over the rev. gentleman, because we to-day understand the nature of glacial periods much better than we did fifteen or twenty years ago, when he wrote.

In consequence of the greater acquaintance with the subject which geologists now have, we know that each glacial epoch contained within it a set of warm periods as well as of cold ones, and that the tropic forms which he has relied upon would flourish during any one of them. These hot and cold periods were complimentary to each other in a glacial epoch, and their occurrence, as testified to by these shells, is strongly confirmatory of the occurrence of such an epoch.

If we take the evidence and examine it separately, we find that it confirms this view; for instance, Woods mentions the fossil shell *Fusus colossus*, found in Western Australia, and points out that it is now represented only by species confined to the tropics. Therefore he tells us that colony cannot have experienced a cold period. I contend that the evidence proves no more than this, that a warm climate prevailed there when that fossil flourished, and that its occurrence is not inconsistent with the prevalence of a cold climate shortly before and shortly afterwards.

In a South African pliocene formation a fossil (*Venericardia*) is abundant. The shell-fish has abandoned the coast, and is now found only within the tropics. According to Mr. Woods, this should be evidence that South Africa has never been subjected to an arctic climate; and yet immediately below the limestone containing this fossil a deposit of till, scratched rocks, and other glacial indications are found (*C. and T.*, p. 242).

Again, the tropic shells of South Australia are in formations which have for neighbours glacial drifts and grooved rocks. Indeed, we need not go further than Mr. Woods' own writings to find counter arguments. That gentleman has carefully described the crag formations of that colony, and he has identified them with the typical crag of Norfolk (*Geo. Obs. of South Australia*, p. 178). Now, this crag indicates a cold climate. Lyall says that "the fauna of the upper crag is very arctic in character" (*Principles*, Vol. I., pp. 197-9). The only deduction which the evidence warrants is that the climate was fluctuating, and passing quickly from extreme to extreme, as it does in every glacial period. Dr. Duncan confirms this view, after a careful examination of the fossiliferous limestone of the cliffs of the Australian Bight; for he says that its contents indicate a change of climate, an alteration in the distribution of marine animals, and an elevation of the land (Wallace's *Australia*, p. 78).

I feel, therefore, that the evidence which Mr. Woods marshals in array against the occurrence of a glacial climate here may be dismissed as inconclusive.

IV.

Let me ask, What interpretation can be put upon all the different facts which I have thrown together if the glacial theory is rejected?

We shall have to believe that since the pliocene era commenced Victoria has been elevated and depressed to a considerable extent at least five or six times. Surely these great movements would have involved a degree of flexure of the earth's crust in these regions such as must have left behind it great traces in the tertiary deposits.

And yet, when we search for such traces we cannot find any. Undisturbed sedimentary deposits overlie the upturned edges of our palæozoic rocks.

Sir Andrew Clark in 1855 reported to our Government that the "tertiary beds" of the southern parts of Victoria "are always (a few cases of local disturbance excepted) either horizontal, or dip at very small angles—viz., 1 deg. to 5 degs." *(Geo. Sur. Vict.*, 1855, p. 9).

The limestone pliocene deposits of Mount Gambier, S.A., are reported to be perfectly horizontal also. Woods tells us that an area of many thousand square miles is "occupied by one formation without alteration of level, break, or interruption. . . . The strata occur in nearly every case parallel with the horizon" *(Geo. Obs. S. A.*, pp. 59, 60).

The tall cliffs which wall in the Great Australian Bight for hundreds of miles are reported to be fairly level throughout the whole distance.

A. W. Howitt, writing of the Murray Plains in an official report, remarks that "the elevation and depression of the land from far back in tertiary times have been equable and regular over wide districts" (*Geo. Sur. Vict.,* Vol. II., p. 80).

If we turn our eyes to South America we find exactly the same condition of things.

Although the east coast has no less than seven elevated sea beaches, the topmost one being 1400 feet above the ocean, there is no flexure to indicate movements of the earth's crust, and no dislocation of the formations. Darwin tells us that the beaches preserve an altitude which does not vary 10 feet throughout a distance of 700 miles. They excited on his part expressions of the utmost wonder from their extraordinary degree of horizontality. On the west coast, where volcanic action is elevating the surface, the raised beaches can be traced for a distance of 2000 miles; but they, on the contrary, show the utmost irregularity in altitude, and are much "thrown" in parts (Darwin's *Notes on Geo. of So. Am.*, pp. 53-55).

The evidence of frequent alterations in the relative levels of land and sea in the Southern Hemisphere is as abundant as that of flexure and fracture in the superficial deposits of the crust is rare.

Oscillations of the ocean, due to cosmical causes, better fit the conditions; they explain all the facts more simply, and they harmonise with the glacial theory.

I have now completed the task I had set myself, and hasten to conclude.

We have seen that, owing to various obscure causes, Victoria must have its climate lowered at various times. On the last occasion a miocene plateau, of great height and undetermined area, was ground off the face of the country by glacial ice. Its non-auriferous sandstone yielded the valueless early washes of our goldfields (Selwyn's *Geo. Obs. Vict.*, p. 22). The poor upper silurian shales and slates were next reached, and scoured away over wide tracks, and these yielded the inferior washes of middle date; and last, the rich lower silurian rock was uncovered, and literally quarried away by wedge of frost and chisel of ice, and the *débris* was reduced to boulders, gravel, sand, and clay in the glacier battery. These products, ground-sluiced by the ice-waters, remain behind as the golden washes of the latest period.

We have seen that these operations were not continuous, but were interrupted by periods of warmer temperature. With these changes the ocean oscillated, its waters now rising until Australia was an archipelago, and anon sinking until Bass's Straits were dry land, and a promontory stretched its long horn far southward of Tasmania. And while these operations were proceeding the flora and fauna were being shifted from point to point, exterminated, renewed, and varied in a remarkable manner.

Such is a bald sketch of the picture which presents itself to the mind as one reviews the evidence by the light of the geological revelations of the Northern Hemisphere. It appears to me that a glacial climate in Victoria during post-miocene times will account for many local phenomena which are not explained by the fluvial theory, and will render intelligible many of the peculiarities of our deep leads and of our alluviums.

ART. II.—*The Recent Red Sunsets.*

BY PROFESSOR ANDREW.

[Read 13th March, 1884.]